ANALYSIS OF THE CAUSES AND CONSEQUENCES OF SUBMARINE SLOPE FAILURE

Lincoln F. Pratson
Institute of Arctic and Alpine Research
University of Colorado, Boulder, CO, 80309-0450
phone: (303) 492-6752, fax: (303)492-6388, e-mail: Lincoln.Pratson@Colorado.EDU

LONG-TERM GOALS

Develop: (i) measurements of seafloor morphology that can provide relative but rapid indications of submarine slope stability from bathymetry and high-resolution seismic data; (ii) statistical methods for estimating sediment properties that influence slope stability in areas between and beyond where data exists; and (iii) numerical models of the sediment flows spawned by slope failure and the manner in which they modify continental margin bathymetry and stratigraphy.

SCIENTIFIC OBJECTIVES

- Use estimates of the state of stress in a submarine slope to constrain the likelihood and potential mode of slope failure.
- Establish a method for correlating down-core, sedimentological measurements marred by sediment deformation, anomalous deposits, and varying sediment accumulation and/or erosion.
- Simulate sediment flow erosion, transport and deposition, and its impact on seafloor evolution and stratigraphy formation.

APPROACH

- Collaborate with Ulisses Mello (IBM Watson Research Labs), an expert in numerical methods, to derive: first, an analytical solution for the state of stress in two dimensions in a simple, homogeneous, submarine slope; and second, a numerical solution of the state of stress in slopes with more complicated geometries and that are composed of heterogeneous sediments.
- Collaborate with Doug Martinson (Lamont-Doherty Earth Observatory), an expert in statistics, to develop a statistical algorithm that relates any two geologic time series on the basis of a combined weighted comparison of their amplitudes and shapes.
- Collaborate with Gary Parker (University of Minnesota) and James Syvitski (INSTAAR), experts in sediment dynamics, in developing a 2-D, layer-averaged simulation of turbid flows.

WORK COMPLETED

- A general, analytical solution has been derived for the state of stress in two dimensions in a simple, homogeneous slope. The solution has been coupled with the solution for pore pressures generated by transient fluid flow. It has also been applied toward explaining the geometry of the Humboldt slide in the Northern California STRATAFORM study area.
- A prototype of the correlation algorithm has been developed, and has been excercised on synthetic down-core records.
- A 2-D, marker-in-cell algorithm of turbidity current dynamics has been developed. The algorithm has been used to simulate the movement of a turbidity current over multibeam bathymetry of both the Northern California and New Jersey STRATAFORM study areas.

RESULTS

- The 2-D state of stress solution for a simple, homogeneous slope offers an explanation for the geometry of the Humboldt slide and similar slope failures worldwide. It suggests that such failure geometries are formed under a compressional stess field.

	Form Approved OMB No. 0704-0188

Report Documentation Page

1. REPORT DATE **30 SEP 1997**	2. REPORT TYPE	3. DATES COVERED **00-00-1997 to 00-00-1997**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Analysis of the Causes and Consequences of Submarine Slope Failure	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Colorado,Institute of Arctic and Alpine Research,Boulder,CO,80309**	8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

- The prototype correlation algorithm correclty identifies the true correlation between synthetic down-core records deformed by variable sedimentation, interspersed with random deposits, and missing sections due to erosion.
- The turbidity-current algorithm is able to simulate the spreading and elongation of a turbidity current as it moves downslope. It also predicts the path a turbidity current will follow over the seafloor.

IMPACT/APPLICATIONS

- Estimating the state of stress in a submarine slope appears to offer an important new approach for understanding the stability of the slope and how it may fail.
- The prototype correlation algorithm is a significant step toward a reliable method for extracting meaningful correlations between sediment records from siliclastic shelf and slope stratigraphy.
- The 2-D turbidity current algorithm offers a tool for understanding how these processes contribute to the 3-D evolution of continental margin morphology and stratigraphy.

TRANSITIONS

- The results of the slope stability analysis support the seismic interpretations of Gardner et al. (special STRATAFORM issue of Marine Geology) as to the geometry of the Humboldt slide.
- The correlation algorithm is still under development, but will eventually aid in correlating down-core measurements to seismic reflection data, and from one core site to another.
- The 2-D turbidity current algorithm represents will be used in a 3-D seascape and stratigraphy evolution model being developed in collaboration with J. Syvitski.

RELATED PROJECTS

- Work has begun on developing a data base of continental margin morphology, sedimentology, oceanography and tectonics with support from MOBIL Technology Center,.
- A collaboration with G. Parker and C. Paola (University of Minnesota) has been initiated to simulate seismic reflection profiles of experimental shelf and slope stratigraphy produced in a large laboratory flume.
- Work is being done with the National Geophysical Data Center to construct merged topography-bathymetry grids of the US coastal zone at a resolution of 3 arc seconds (~90 m).

REFERENCES (FY97 ONLY)

Pratson, L.F., M. Garcia, G. Parker, H. Lee and B. Coakley, 1996, Mass movements on continental slopes: *Oceanography*, v. 9, p. 168-172.

J. Goff, L. Mayer, J. Hughes-Clarke, and L.F. Pratson, 1996, Swath mapping on the continental shelf and slope: the Eel River basin, Northern California: *Oceanography*, v. 9, p. 178-182.

Pratson, L.F., and M. Edwards, 1996, Advances in Seafloor Mapping using Side-scan Sonar and Multibeam Bathymetry: *Marine Geophysical Researches* (special issue), v. 18.

Pratson, L.F. and M. Edwards, 1996, An introduction to advances in seafloor mapping using side-scan sonar and multibeam bathymetry in L.F. Pratson and M. Edwards (eds.), Advances in Seafloor Mapping using Side-scan Sonar and Multibeam Bathymetry (special issue): *Marine Geophysical Researches*, v. 18, p. 601-605.

Pratson, L.F. and W.B.F. Ryan, 1996, Automated drainage extraction in mapping the Monterey submarine drainage system, California, in L.F. Pratson and M. Edwards (eds.), Advances in Seafloor Mapping using Side-scan Sonar and Multibeam Bathymetry (special issue): *Marine Geophysical Researches,* v. 18, p. 757-777.

M.A. Seidl, J.K. Weissel, and L.F. Pratson, 1996, The kinematics and pattern of escarpment retreat across the rifted continental margin of southeast Australia: *Basin Research*, v. 8, p. 301-316.

Pratson, L.F., and J.P. Syvitski, 1996, Modeling rates of submarine canyon evolution on continental slopes (abs.): *EOS Transactions of the American Geophysical Union*, v. 77, p. F. 329.

Pratson, L.F., and W.F. Haxby, 1997, Panoramas of the Seafloor: *Scientific American*, June, p. 66-71.

Syvitski, J.P.M., L. Pratson, M. Perlmutter, P. de Boer, G. Parker, M. Garcia, P. Wiberg, M. Steckler, D. Swift, and H. Lee, 1997, EARTHWORKS: a large-scale and complex numerical model to understand the flux and deposition of sediment over various time scales, in V. Pawlowsky-Glahn (ed.): *Proceedings of IAMG'97, the third annual conference of the International Association of Mathematical Geology*, CIMNE-Barcelona, v. 3, p. 29-33.

Syvitski, J, L. Pratson, and M. Moorehead, in press, Earthworks: a large spatial-scale numerical model to study the flux from land to the ocean and depositional re-working of sediment in ocean basins over various time scales (abs): *EOS Transactions American Geophysical Union.*

Mello, U., and L.F. Pratson, in review, Constraints on submarine slope stability from the state of stress in an infinite slope: *Marine Geology.*

Syvitski, J.P.M, L.F. Pratson, D. O'Grady, in review, Stratigraphic predictions of continental margins for the Navy, in L. Whatney et al. (eds.), Numerical Experiments in Stratigraphy: *SEPM Special Publication.*

McAdoo, B., L. Pratson, D. Orange, in press, Comparative Landslide Morphology, U.S. Continental Slope (abs): *EOS Transactions American Geophysical Union.*

Pirmez, C., L.F. Pratson, M.S. Steckler, in review, Clinoform development by advection-diffusion of suspended sediment: modeling and comparison to natural systems: *Journal of Geophysical Research..*

SELECTED WEB SITES HIGHLIGHTING RESULTS OF:

Pratson, L.F., and W. Haxby, 1996, What is the slope of the U.S. continental slope?: *Geology*, v. 24 p. 3-6.

http://www.ldeo.columbia.edu/us_margins/index.html
http://www.smithsonianmag.com/smithsonian/issues97/apr97/seafloor.html
http://www.nsf.gov/od/lpa/news/publicat/frontier/12-96/12exotic.htm
http://www.geosociety.org/pubs/geo9601.htm
http://www.columbia.edu/cu/record21/record2113.20.html
http://geosun1.sjsu.edu/~dreed/105/exer2e.html
http://hydro.geosc.psu.edu/Sed_html/marine_geo.html

WEB SITES HIGHLIGHTING RESULTS OF:
Pratson, L.F., and W.F. Haxby, 1997, Panoramas of the Seafloor: *Scientific American*, June, p. 66-71.

http://www.sciam.com/0697issue/0697pratson.html
http://www.pourlascience.com/numeros/pls-238/art-3.html

WEB SITES HIGHLIGHTING RESULTS OF:
Pratson, L.F., and B.J. Coakley, 1996, A model for the headward erosion of submarine canyons induced by downslope eroding sediment flows: *Geological Society of America Bulletin*, v. 108, p. 225-234.

http://www.geosociety.org/pubs/9602bul.htm#S8

WEB SITE HIGHLIGHTING BATHYMETRY-TOPOGRAPHY COMPILATION OF THE U.S. COASTAL ZONE BEING DONE IN COLLABORATION WITH NGDC-NOAA:

http://www.ngdc.noaa.gov/mgg/bathymetry/fusion.html